SEMI-AUTOMATIC SYSTEM FOR WATERFLOOD SURVEILLANCE

Tadeusz Patzek and Dmitriy B. Silin
Contact: Tadeusz Patzek, 510/643-5834, patzek@patzek.berkeley.edu

RESEARCH OBJECTIVES

A successful waterflood requires proper operation of individual wells in a pattern as well as maintained balance between water injection and production over an entire project or field. Aggressive or unbalanced injection leads to reservoir rock damage and consequent loss of wells caused by shear failure of reservoir rock and overburden.

Our ultimate goal is to design an integrated system of field-wide waterflood surveillance and supervisory control. Recently, we have introduced a new element of our system, satellite images of the field surface through Synthetic Aperture Radar Interferograms (InSAR).

APPROACH

Damage to heterogeneous soft rock caused by water injection is not well understood yet. Rock damage causes water recirculation between injectors and producers without the desirable pressure support and increased oil recovery. Water-swept, pressurized regions in the reservoir cause less surface subsidence, the evolution of which shows up on satellite images with remarkable accuracy and clarity.

ACCOMPLISHMENTS

1. Injection into a Layered Reservoir

Injection into a layered reservoir is extremely difficult. Usually, “thief-layers” or highly conductive channels of damaged rock exist. Recently, we have designed an optimal injection controller for mixed transient/steady-state flow in a layered formation. The objective of the controller is to maintain the prescribed injection rate in the presence of hydrofracture growth and injector-producer linkage. The history of injection pressure and cumulative injection, along with estimates of the hydrofracture size, are the controller inputs. After analyzing these inputs, the controller outputs an optimal injection pressure for each injector.

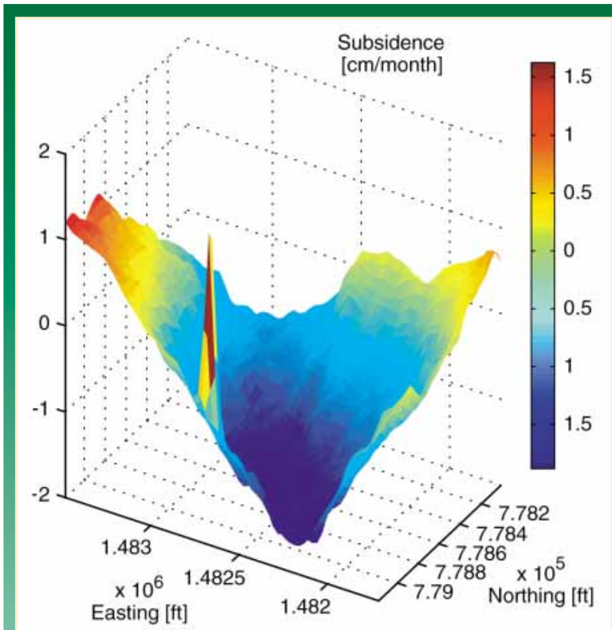

Figure 1. Monthly subsidence bowl in cm/month, Lost Hills, CA, 1999; Sections 4, 5, 29, 32, and 33

2. InSAR Image Analysis

Between April 1995 and December 1999, we analyzed ten differential InSAR images of the South/North Belridge and Lost Hills diatomite fields in California (Figure 1). The images show that the rate of subsidence has decreased in some parts of Lost Hills and Belridge while it increased in others. We have been able to demonstrate the remarkable behavior of both fields:

(a) There is recirculation of injected water through the "tubes" of damaged soft rock that link injectors with producers, resulting in diminished pressure support from the waterfloods.

(b) Consequently, despite more water injection, there is more subsidence in Sections 29, 34, and 33 in Belridge, and in Sections 29, 4, 5, and 32 in Lost Hills.

(c) Because much of the injected water is recirculated, the rate of subsidence is proportional to water production rate.

(d) Compaction remains an important mechanism of hydrocarbon production.

(e) In addition to accelerated compaction in the densest and most advanced waterfloods, there is a sizable oil production response to water injection.

SIGNIFICANCE OF FINDINGS

Our work, done in collaboration with Chevron and Case Services, will result in higher ultimate oil recovery and lower well losses in two giant oilfields in California. A preliminary patent application has been filed.

RELATED PUBLICATIONS

Patzek, T.W., and D.B. Silin, Use of InSAR in surveillance and control of a large field project, 21st Annual Int. Energy Agency Workshop and Symposium, Edinburgh, Scotland, 2000.

Patzek, T.W., and D.B. Silin, Control of fluid injection into a low-permeability rock: 1. Hydrofracture growth. TIPM, July 2001.

Silin, D.B., and T.W. Patzek, Water injection into a low-permeability rock: 2. Control model. TIPM, July 2001.

Patzek, T.W., D.B. Silin, and E. Fielding, Use of satellite radar images in surveillance and control of two giant oilfields in California, SPE 71610, 2001.

ACKNOWLEDGMENTS

This work has been supported by the Assistant Secretary for Fossil Energy, Office of Natural Gas and Petroleum Technology, through the National Petroleum Technology Office, Natural Gas and Oil Technology Partnership, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.